

Claims

- 1. Method for preventing contamination on the surfaces of optical elements with a multilayer system during their exposure to EUV radiation at signal wavelength in an evacuated closed system having a residual gas atmosphere, in which the photocurrent generated by photoemission from the radiated surface of the multilayer system is measured, and the photocurrent is used to control the gas composition of the residual gas, **characterized in that** the gas composition of the residual gas is altered as a function of at least one lower and one upper threshold value of the photocurrent.
2. Method as claimed in Claim 1, **characterized in that** the threshold values of the photocurrent are selected from the range between the minimum photocurrent I_{\min} and the maximum photocurrent I_{\max} , which occur when the minimum and the maximum of the electric field intensity of the standing wave, which forms in the multilayer system when the incident signal wavelength is reflected, lie in the free interface of the multilayer system.
3. Method as claimed in Claim 1, **characterized** by the following steps:
 - a) Measuring a first value of the photocurrent at the start of the EUV radiation after the subsidence of transient effects and storing this value as a first threshold value S_1 ,
 - b) Defining at least one second threshold value $S_{2,i}$ for the photocurrent, where $i = 1, 2, 3, \dots$, such that $S_1 > S_{2,i}$ or $S_1 < S_{2,i}$,

- c) Measuring the photocurrent during the ongoing EUV radiation,
 - d) Controlling the gas composition during the radiation as a function of the measured photocurrent by supplying at least one gas to the closed system before or when the second threshold value $S_{2,i}$ is reached or exceeded and subsequently at least reducing the supply of this gas before or when the first threshold value S_1 is reached or exceeded.
4. Method as claimed in any one of Claims 1 to 3, **characterized** by the following steps:
- a) Measuring a first value of the photocurrent at the start of the EUV radiation after the subsidence of transient effects and storing this value as a first threshold value S_1 ,
 - b) Defining at least one second threshold value $S_{2,i}$ for the photocurrent, where $i = 1, 2, 3, \dots$, such that $S_1 > S_{2,i}$ or $S_1 < S_{2,i}$,
 - c) Measuring the photocurrent during the ongoing EUV radiation,
 - d) Controlling the gas composition during the radiation as a function of the measured photocurrent by supplying at least one gas to the closed system before or when the first threshold value S_1 is reached or exceeded and subsequently at least reducing the supply of this gas before or when the second threshold value $S_{2,1}$ is reached or exceeded.

5. Method as claimed in any one of Claims 1 to 4, **characterized in that** a gas is supplied which is already contained in the residual gas atmosphere, such that the partial pressure of this gas is changed.
6. Method as claimed in any one of Claims 1 to 5, **characterized in that** a gas is supplied which is not contained in the residual gas atmosphere before said supply.
7. Method as claimed in any one of Claims 1 to 6, **characterized in that** carbon monoxide, carbon dioxide, hydrogen, water, oxygen, nitrogen, SF₆, He, Ne, Ar, Kr, Xe, alkanes, alkenes, alkynes, alcohols, ketones, aldehydes and/or other hydrocarbons, formic acid, acetic acid, propionic acid, hydrogen peroxide, hydrazine, N₂O, NO, NO₂, SO₂ and/or other oxygen-containing gases, F, Cl, Br, I, chloromethane, dichloromethane, trichloromethane, carbon tetrachloride, carbon tetrafluoride, fluoromethane, difluoromethane, ammonia, phosphine, antimony hydride, hydrogen fluoride, hydrogen chloride, hydrogen bromide, hydrogen iodide, boron fluoride, diborane, nitrogen trifluoride, hydrogen sulfide, hydrogen selenide, hydrogen telluride and other halogen/hydrogen-containing gases is/are supplied.
8. Method as claimed in any one of Claims 1 to 7, **characterized in that** a plurality of second threshold values $S_{2,i}$ are defined, where $|S_{2,i+1} - S_1| \leq |S_{2,i} - S_1|$ or $|S_{2,i+1} - S_{2,i}| \leq |S_{2,i} - S_{2,i-1}|$ where $i = 1, 2, 3, \dots$

9. Method as claimed in any one of Claims 1 to 8, **characterized in that**, before the EUV radiation, the position of the closest minimum and/or reversal point and/or the maximum (curve position) of the electric field intensity of the standing wave forming in the multilayer system when the incident signal wavelength is reflected is determined relative to the free interface of the multilayer system and the second threshold value $S_{2,i}$ is defined as a lower or an upper threshold value as a function of the curve position relative to the first threshold value S_1 .
10. Method as claimed in any one of Claims 1 to 9, **characterized in that**, in an optical element with a surface susceptible to oxidation, a carbonizing gas composition is adjusted prior to EUV radiation.
11. Method as claimed in Claim 10, **characterized in that** a carbon-containing gas is supplied before the first threshold value S_1 is reached.
12. Method as claimed in any one of the preceding claims, **characterized in that** the measured photoelectrons are converted into the time integral of the corresponding current.
13. Method as claimed in any one of the preceding claims, **characterized in that** the gas is delivered in the proximity of the surface of the optical element.

14. Device for controlling the contamination on the surface of at least one optical element during the exposure to EUV radiation, comprising a detection unit (42, 42, 43) for the photoelectrons emitted by the optical element, an evaluation unit (5) connected to the detection unit and a control unit (6) connected to the evaluation unit and to a gas delivery unit (71, 72), wherein the evaluation unit (5) is configured to compare the measured photocurrent with at least two stored threshold values of the photocurrent and to supply threshold-dependent signals to the control unit (6).
15. EUV lithographic device with optical elements (2), wherein a detection unit (41, 42, 43) for photoelectrons is mounted in the proximity of at least one of the optical elements (2) and is operatively linked to an evaluation unit (5). **characterized in that** a control unit (6) is connected to the evaluation unit (5) and is operatively linked to at least one gas delivery unit (71, 72), wherein the evaluation unit (5) is configured to compare the measured photocurrent with at least two stored threshold values of the photocurrent and to supply threshold-dependent signals to the control unit (6).
16. Device as claimed in Claim 14 or 15, **characterized in that** the detection unit (41, 42, 43) comprises an electron collector, e.g., a detection ring (41) or a detection network disposed above the surface of the optical element, which is arranged and/or configured in such a way that it does not affect the incident EUV radiation.
17. Device as claimed in any one of Claims 14 to 16, **characterized in that** the gas delivery unit has at least one gas feed (71).

18. Device as claimed in Claim 17, **characterized in that** the gas feed (71) is arranged adjacent to the surface of the optical element (2).
19. Device as claimed in any one of Claims 14 to 18, **characterized in that** a residual gas analyzer (8) is connected to the evaluation unit (5).
20. Device as claimed in any one of Claims 14 to 19, **characterized in that** the evaluation unit (5) and the control unit (6) are combined into a closed-loop control unit.
21. Method for cleaning carbon-contaminated surfaces of optical elements by exposure to EUV radiation in an oxygen-containing atmosphere, **characterized in that** the photocurrent generated during radiation by photoemission from the surface to be cleaned is measured and, if at least two predefined threshold values of the photocurrent are exceeded or fallen short of, at least one gas is supplied or the supply of at least one gas is interrupted.